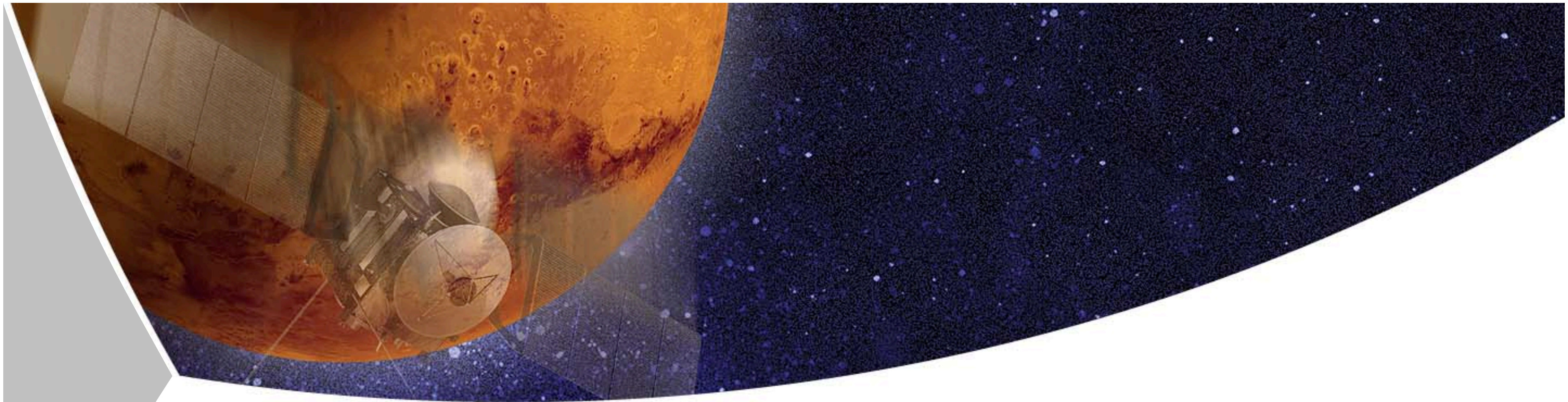


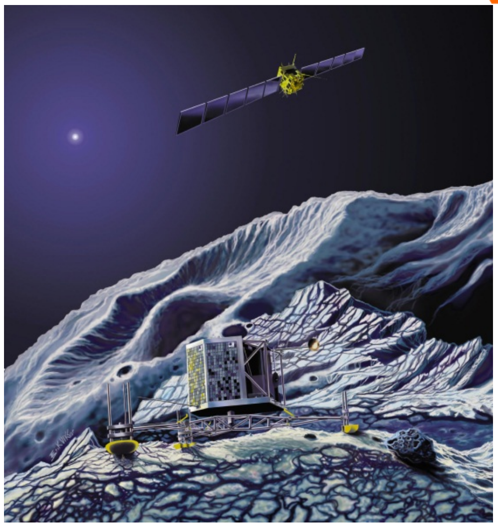
MAGIC (‚Mobile Generic Instrument Carrier‘)
A mobile and autonomous landing package for small body exploration based on MASCOT

June 9th, 2011

T. Van Zoest, T.-M. Ho, C. Lange, S. Wagenbach, L. Witte (DLR)
& the MASCOT Study Team

Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Small Asteroid Lander MASCOT

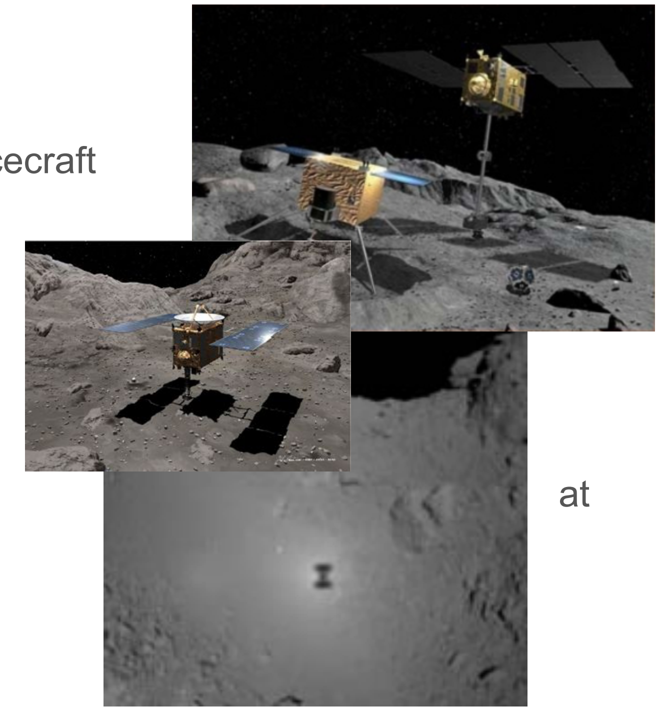


- „Mobile Asteroid Surface SCOuT“ is a dedicated landing package for in-situ science on small bodies
- proposed by DLR Bremen for ESA MARCO POLO mission as well as for JAXA HAYABUSA follow-on mission
  - latter opportunity currently envisaged
- its dimensions lie in between those of previously designed small-body landers
  - HAYABUSA small lander MINERVA ≈1 kg
  - ROSETTA comet lander PHILAE ≈ 96 kg
- MASCOT offers good compromise:
  - low mass system (10 kg)
  - with still extensive payload capability (3 kg)

MASCOT – History of Origins

2008 - MASCOT was proposed by DLR Bremen in response to the ESA Marco Polo Declaration of Interest for a mobile asteroid lander package to:

- Serve as "**scouting vehicle**"
  - To guide the sampling site selection of the main spacecraft
- Conduct "**context science**"
  - To provide ground truth for the remote sensing observations and the returned sample analyses
- Accomplish "**stand-alone science**"
  - Comprehensive *in situ* science at microscopic scale at more than one location (mobility)
  - Geophysical investigations, obtaining internal properties of the NEO

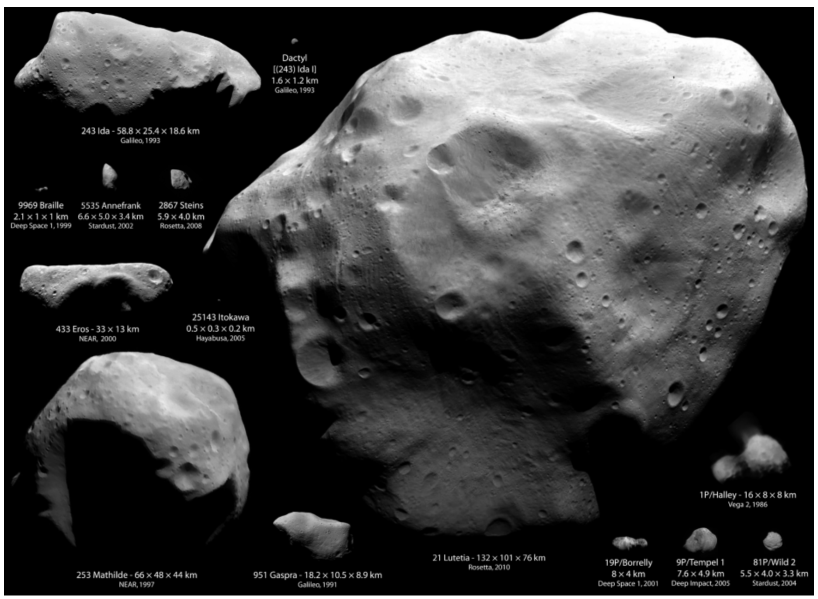


©ESA/ESTEC/JAXA

ESA selected the proposal for a feasibility study which was subsequently conducted from 2009 – August 2010 at the DLR in collaboration with JAXA, CNES and further European institutes and universities.

Landing and Mobility on Small Bodies

- **landing and mobility on small bodies implies several challenges…**
  - small body dimensions result in very low gravity ($10^{-5} \dots 10^{-4}$ m/sec²)
  - leads to rebouncing at touch-down and high escape risk
  - properties are widely unknown and show wide range
    - e.g. shape, rotational state, surface properties

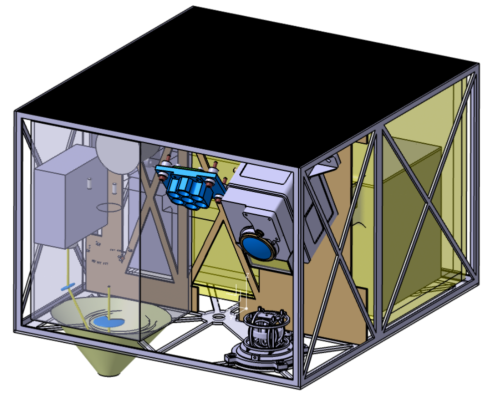


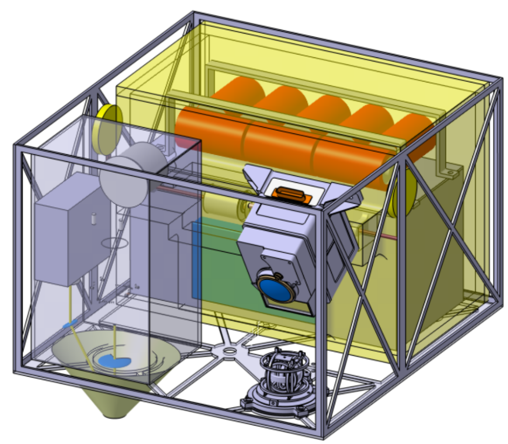
…which cause high uncertainty during design of lander

- support by comprehensive landing analysis and detailed mobility dynamics investigations is essential
  - MASCOT offers robust landing and mobility concept

MASCOT System Baseline

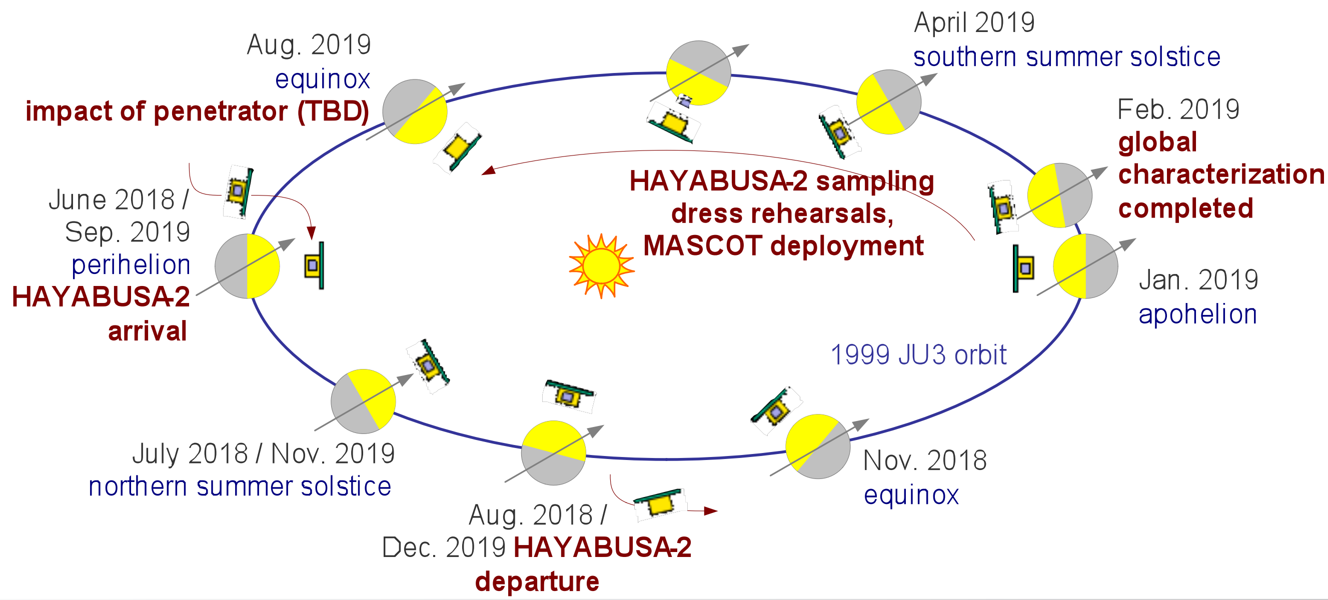
- **Total Surface Package mass ~ 10 kg & Total Scientific Payload mass ~ 3 kg**
  - High payload to system mass ratio: 0.3
- **Completely autonomous on-asteroid operation**
- **Mobility :**
  - Uprighting
  - Relocation on-surface (‘Hopping’)
- **Configuration: Body with fixed instrument accommodation**
- **Structure: no boxes, but highly integrated structure (including common electronics box)**
- **Subsystems: highly integrated approach for all subsystems, passive and low risk system, communication using synergies with the carrier-spacecraft**



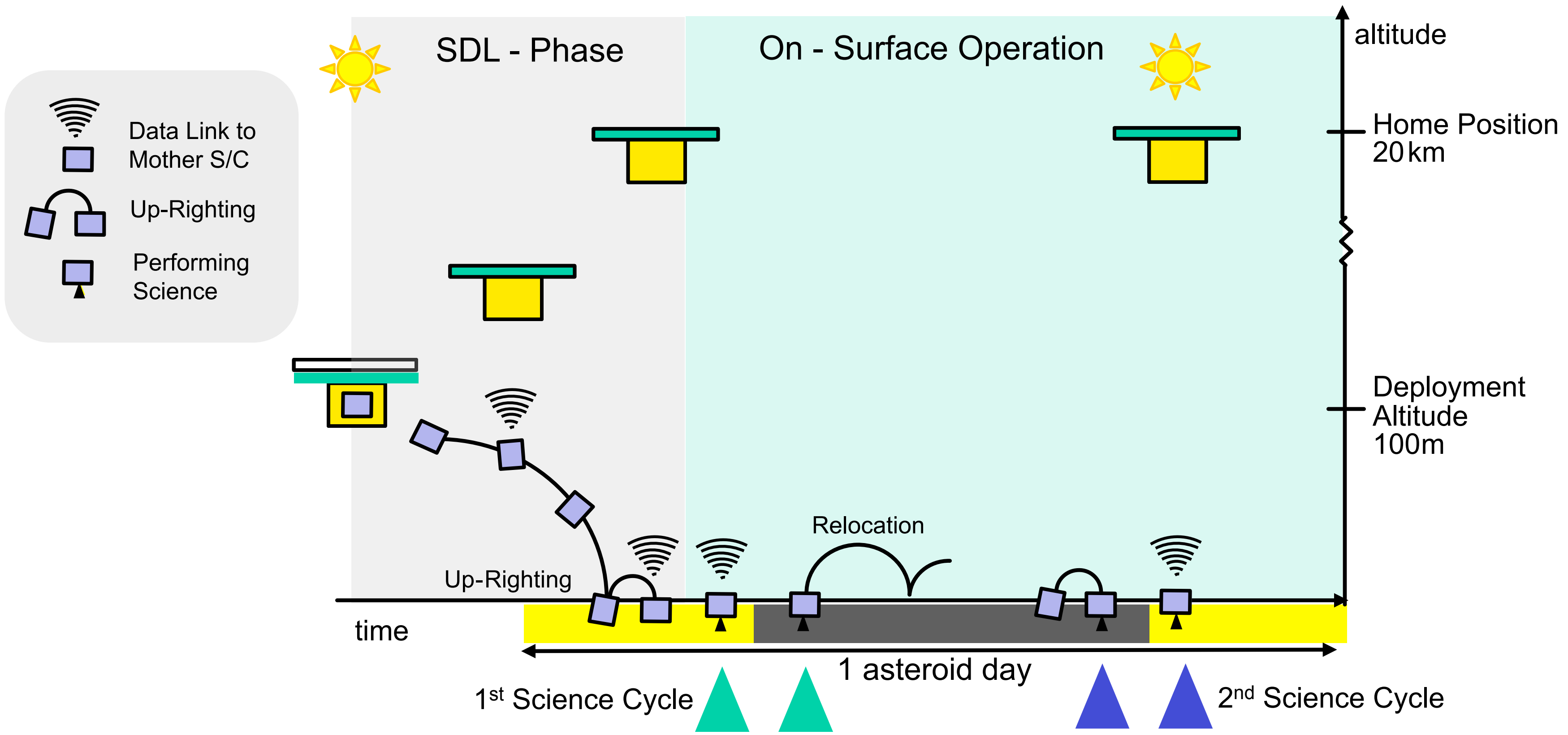


Mission Description

- **HAYABUSA-2 launch in 2014/15 → arrival at asteroid 1999 JU3 in June 2018**
- **MASCOT deployment during sampling dress rehearsal maneuver of mother s/c**
  - after completed global characterisation due to safety
  - after solstice in April 2019 due to thermal restrictions
  - → June...August 2019



Operational Sequence



Note: 16hrs total operational lifetime = 2 asteroid days

Attitude Determination and Mobility

Tasks after SDL Phase

Attitude

(1) Detect landing shock and final rest position.

(2) Determine the position on the surface wrt. to distance, angle to the surface and orientation

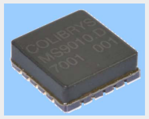
Mobility

(2) Correction of the position or orientation (up-righting) to be able to perform science cycle

(3) Relocate MASCOT after successful completion of one science cycle

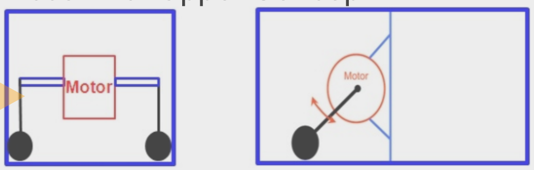
Concepts

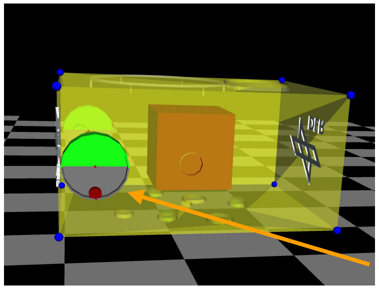
Infrared distance sensor



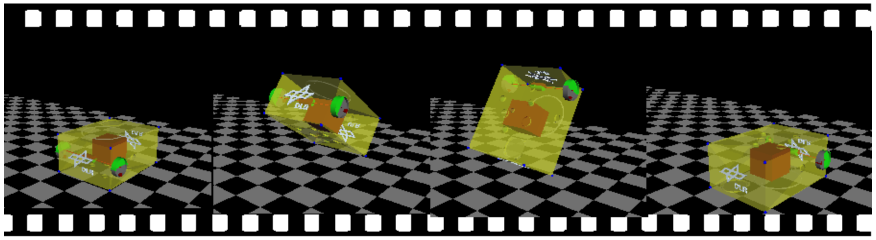
Accelerometer

Eccentric Tappet Concept





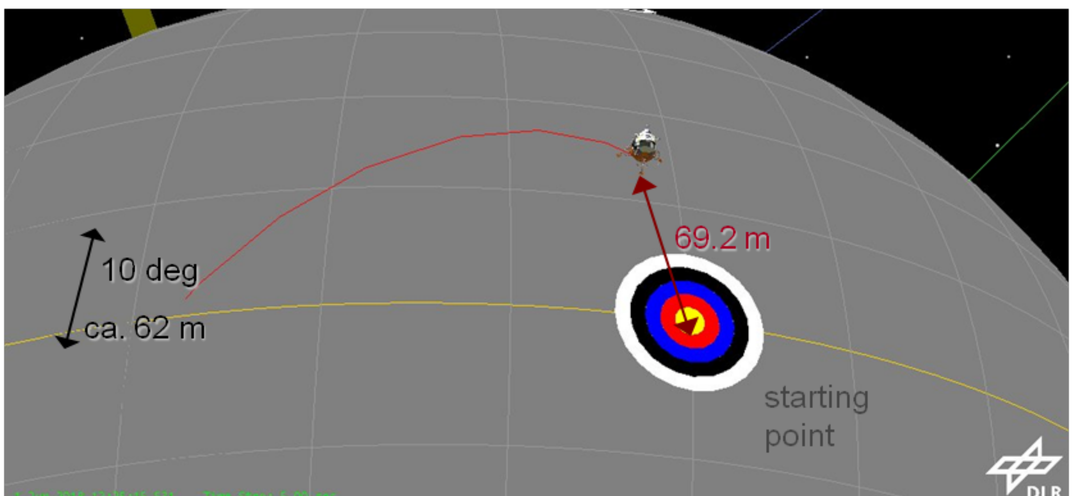
Extender tappet on both sides of lander



Post Landing Mobility Analysis

alpha 60 deg, jumping in direction of (nearest) pole -> best case				
starting point		**distance ***	**max. altitude**	**duration**
equator (latitude 0 deg)	longitude 0 deg, r = 460 m	69.2 m	31.6 m	1515 s (25 min)
	longitude 90 deg, r = 390 m	45.4 m	20.8 m	974 s (16 min)
latitude 45 deg	longitude 0 deg, r = 423 m	53.2 m	29.4 m	1284 s (21 min)
	longitude 90 deg, r = 373 m	37.8 m	19.8 m	881 s (15 min)

* linear distance, not real ellipsoidal segment



- note: hopping along equator with 60 deg or 120 deg against surface results in similar distances

snapshot from STK scenario:
MASCOT landed after hopping
latitude = longitude = 0 deg
angle = 60 deg in direction of pole,
delta-v = 10 cm/s

Possible Scientific Payloads

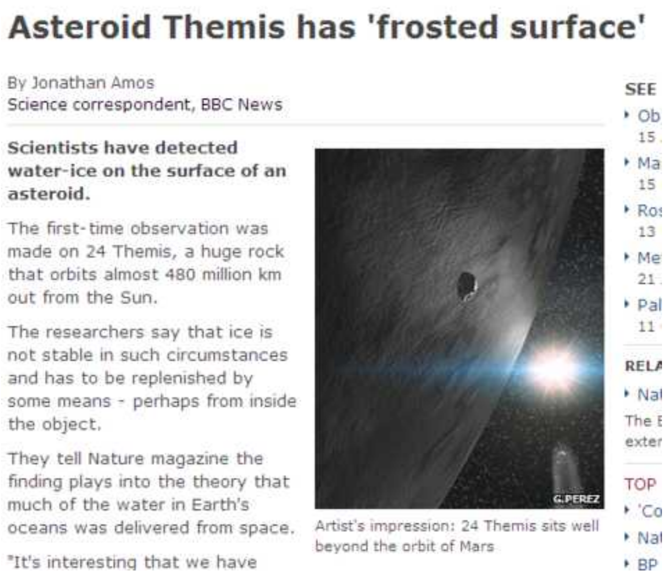
Every combination of instrumentation under 3kg total mass is possible, depending on the scientific objectives of the mission

Instruments	Science Objectives	MASS [kg]
Alpha-Particle-X-ray Spectrometer	Elemental Composition	0,70
Raman Spectrometer	Mineralogical, inorganic, organic compounds	1,20
Mössbauer Spectrometer	Composition and abundances of Fe-bearing minerals	0,50
Neo-Mole	Subsurface investigation (up to several m depth)	0,90
Evolved Volatiles Ion Trap Analyzer	Ionized evolved gases	0,60
Mid-IR ATR spectrometer	Water, volatiles, minerals species, chemistry, texture	0,20
Ion Laser Mass Analyzer	Elemental, molecular and isotopic composition	2,50
X-ray diffractometer	Composition and material characteristics of minerals	2,00
Optical microscope & IR spectrometer	Composition and micro-structure of minerals	0,50
Mikroseismometer	Surface layering and regolith processes	0,30
Stereo/panoramic camera	Multi-spectral geological terrain imaging	0,60
New Consert	Internal structure 3-D tomography	1,80
Laser-Induced Breakdown Spectrometer	Elemental composition	1,00
Thermal probe	Surface and sub-surface temperature	0,30
Laser Retroreflectors	Determin distance and rotation state	0,50

Science Performance with various P/L combination

- **Example P/L1: a mass spectrometer + volatiles analyzer and mobilty (m < 3kg):**
  - Composition of solid, water ice and volatiles on elemental, molecular (minerals and organics) and isotopic scale at several location on asteroid
  - ➔ Evidence of asteroid being water carrier to Earth
  - ➔ Astrobiology context by constrain the nature of the organic matter delivered to the early Earth for prebiotic chemistry

- **Example P/L2: bistatic radar instrument + thermal probe and with mobility (m < 3kg):**
  - 3D tomography for scanning interior of asteroid to obtain internal structure
  - ➔ Information of collisional evolution of small bodies and its context in Solar System formation history
  - ➔ Hazard avoidance by de-orbiting



Asteroid Themis has 'frosted surface'

By Jonathan Amos
Science correspondent, BBC News

Scientists have detected water-ice on the surface of an asteroid.

The first-time observation was made on 24 Themis, a huge rock that orbits almost 480 million km out from the Sun.

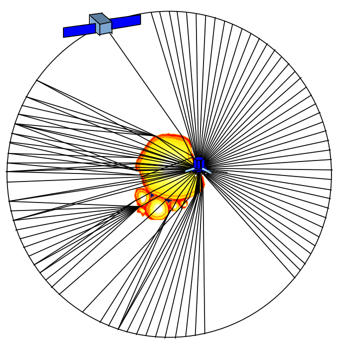
The researchers say that ice is not stable in such circumstances and has to be replenished by some means - perhaps from inside the object.

They tell Nature magazine the finding plays into the theory that much of the water in Earth's oceans was delivered from space.

"It's interesting that we have

G.PEREZ

Artist's impression: 24 Themis sits well beyond the orbit of Mars



Possible Technology Demonstration: Flight Opportunity with Hayabusa-2 (JAXA/ JSPECS)

Mission:

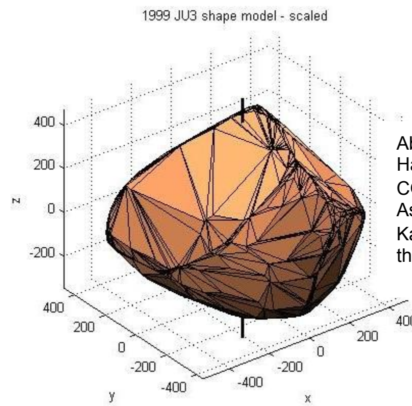
- Launch 2014/15
- Lander deployment: 2018 (release altitude: 100 m)
- Operational lifetime: 16 h = 2 asteroid days

Target: NEO 1999JU3

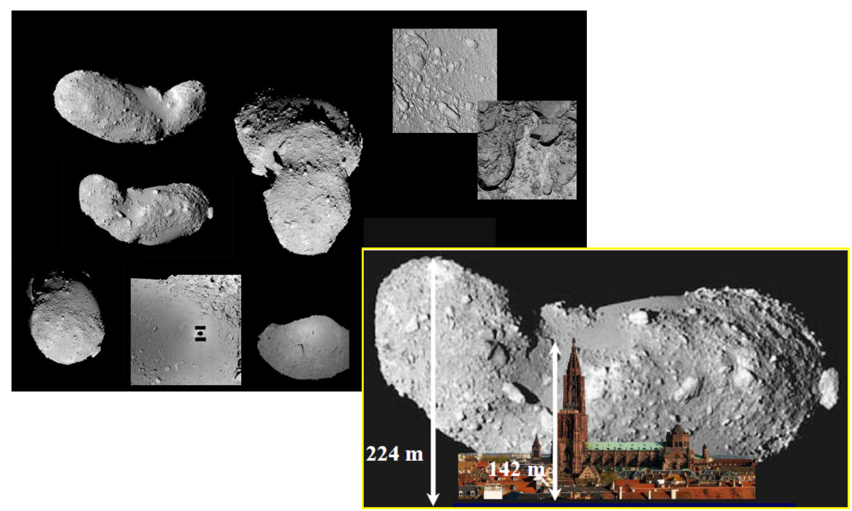
- A C-type near Earth asteroid (organic and maybe containing water)
- Potentially a rubble-pile

Payload: 4 Instruments (total mass = 3 kg)

- Radiometer
- MicroOmega
- WAC
- Magnetometer



Abe, M., Kawakami, K., Hasegawa, S. et al. 2008, COSPAR Scientific Assembly, B04-0061-08.
Kawakami, K. 2009, Master's thesis, University of Tokyo



Summary of MAGIC's Unique Characteristics

- **Unique mobility on asteroid surface**
- **Fully autonomous system**
- **Innovative concept: small flexible platform (comp. "cubesat") with high P/L to system mass ratio for in-situ exploration**
- **Standardization potential: one MAGIC; different payloads**
- **Cheap and fast development (COTS)**
- **Gaining asteroid lander system expertise on European level**
- **Potential for public outreach and education applications: "cube"-lander for educational exploration projects**

SEMS Symposium 2011

3 topics:
- Landing
- Mobility
- Arhitectures

1 day workshop

13 invited speakers

Visits to EADS, OHB Systems, DLR

tim.zoest@dlr.de